

Application
for
United States Patent

To all whom it may concern:

Be it known that, Ohler L. Kinney, Jr., Robert S. Glauz, Brian F. Wright, Kathryn L. Pullen, and Eldon F. Mockry have invented certain new and useful improvements in

Cooling Tower Top Method and Apparatus

of which the following is a full, clear and exact description:

Cooling Tower Top Method and Apparatus

PRIORITY

04/09/03
[0001] This application claims priority to the provisional U.S. patent application entitled, COOLING TOWER METHOD AND APPARATUS, filed November 2, 2001, having a serial number 60/330,896, ^{now abandoned,} the disclosure of which is hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to a method and apparatus for the disposal of heat utilizing a heat exchange liquid. More particularly, the present invention relates to a method and apparatus for a cross-flow water cooling tower wherein the water cooling tower is employed, for example, to dispose of large quantities of heat generated by various industrial processes.

BACKGROUND OF THE INVENTION

[0003] Cooling towers are used in many applications. For example, air conditioning systems for large buildings employ cooling towers for carrying out a portion of the heat exchange that is essential to the cooling process. Industrial processes, such as chemical production, metals production, plastics production, food processing, etc., generate heat that must be disposed of, often by the use of cooling towers. The cooling tower is a housing that channelizes air in proximity to a heat exchange liquid, for example, water. A heat exchange fluid may be circulated through the cooling tower and at least one fan may be mounted on the cooling tower to produce a flow of cooling air in proximity to the heat exchange liquid. Heat is transferred from the heat exchange fluid

to the air, largely through the evaporation of a small percentage of fluid which substantially lowers the temperature of the primary heat exchange fluid. The cooled heat exchange fluid can then return to the industrial process to perform a heat exchange function for either industrial processes or commercial air conditioning systems.

[0004] Conventional cross-flow cooling towers are presently in widespread use in such areas as factory complexes, chemical processing plants, hospitals, apartment and/or condominium complexes, warehouses and electric generating stations. Conventional cross-flow cooling towers are constructed with upright unitary or sectionalized fill structures surmounted by hot water distribution basins and cold water collection basins. The hot water basins are usually equipped with target nozzles or other hot water distributors which distribute the incoming water over the fill. The interior space bounded by the fill structures and the cold water basins define the plenum for the tower. A fan assembly made up of an apertured horizontal deck, which supports an upright, venturi-shaped stack, is positioned at the upper opening of the water cooling tower. This configuration provides a plenum large enough to enable a smooth transition of the flow gas from the generally horizontal direction, through the fill assembly, to the generally vertical direction, and out the exhaust port of the tower assembly. In the operation of the cross-flow cooling towers, hot water is introduced at the top of the fill while the air is introduced along the upright sides of the tower. As the water descends in an even distribution along the fill section, the cooling cross-flow air currents intersect the descending water in a heat exchanging relation. Subsequently, the cooled water is collected in a water basin below while the hot, moist air is discharged into the atmosphere.

[0005] In a cross-flow cooling tower, there is no necessity for the air to make radical changes of direction into the fill and the air inlet is spaced along the entire height of the fill. Therefore, the overall air pressure losses in the fill are usually less than those of a conventional counter-flow tower resulting in the passing of air through the tower more easily.

[0006] Conventional cross-flow cooling towers generally employ various varieties of splash-type fill sections consisting of elongated bars of a specific configuration for dispersing the descending released water. More recently, film type fill sections have been developed which have proven substantially more efficient than splash fill sections. These typically corrugated film fills generally consist of a series of thin, opposed sheets formed of synthetic resin materials in which water passes along the sheets of "film".

[0007] The highest potential for cooling exists at the top of the air inlet sides where the hottest water comes into contact with the coldest air. Once such air has been heated such that the wet bulb temperature of the air is near the water temperature, the air has no more capacity to cool the water, and such heat saturated air prevents the introduction of cooler ambient air into the fill. Air near the top of the tower typically experiences this condition because it initially contacts the hottest water, and all other water along its path of travel is about the same temperature. Air entering near the bottom of the tower initially is exposed to water that has been significantly cooled. As it traverses through the fill, the temperature of the water encountered by the bottom air currents rises, which allows the air to take on more heat.

[0008] The hot water basins in a cross-flow tower are normally constructed to serve as an air seal to prevent air entering the tower through the top of the fill. Additionally, air seals along the length of the tower are provided along the inboard and outboard edges of the basins to seal from the bottom of the basins to the top of the fill. These seals prevent air from entering the spray chamber and bypassing the fill structure. Sealing of the distribution basins also minimizes the contact between incoming air currents and relatively large water particles adjacent the spray nozzles or water distributors.

[0009] Presently, a majority of unitary cooling towers are assembled from a plurality of pieces of sheet metal that are mounted to a metallic support frame. Unitary cooling towers typically are manufactured at a location remote from the installation site. The towers are then shipped to the installation site in a substantially assembled form. Due to the metallic materials with which the cooling towers are assembled, the towers are fairly heavy and therefore require extensive structural support. In addition, the cost of present cooling towers are also adversely affected by the labor intensive processes for manufacturing and assembling the various metallic components of the cooling towers.

[0010] Metallic cooling towers are also subject to corrosion and/or rust. Thus, the metallic towers have a relatively short operational life. Corrosion and/or rust problems can be deterred by employing corrosion and/or rust resistant alloys. However, these metallic materials significantly increase the manufacturing cost of the water cooling tower. Alternatively, plastics such as polyethylene are well known for being moldable into prescribed form and function and are utilized in the art. However, polyethylene material properties are relatively weak and flexible. To compensate for these properties

in monolithic parts, designers must use large quantities of polyethylene to create bigger, thicker and deeper sections to minimize stresses and deflections.

[0011] Accordingly, it is desirable to provide a cooling tower design that offers a substantial reduction in parts, avoiding complex and costly assembly of components. It is also desirable to manufacture a water cooling tower that is light in weight, durable and resists corrosion.

SUMMARY OF THE INVENTION

[0012] The foregoing needs are met, to a great extent, by the present invention where, in one aspect, a cross-flow cooling tower is provided having a frame assembly that is unitarily molded from a plastic material. The frame assembly has opposed top and bottom walls that are parallel to one another along with opposed, parallel side walls that extend between the top and bottom walls. The frame assembly also has opposed, parallel ends that similarly extend between the top and bottom walls. The cross-flow cooling tower additionally has a vertical stack that extends vertically from the top wall. The top covers of the cross-flow cooling tower project outwardly and downwardly from the vertical stack, contacting the side walls and the opposing ends of the water cooling tower.

[0013] In accordance with another aspect of the present invention, a frame assembly is provided having a shell unitarily molded from plastic material. The unitary shell includes opposed parallel top and bottom walls along with opposed parallel end walls. The aforementioned side walls and ends both extend between the top and bottom walls.

[0014] In accordance with yet another aspect of the present invention, a top for a cooling tower is provided having a hot liquid inlet and a generally planar bottom with at least one opening therein for accommodating an air current generator. In addition, the planar bottom has a plurality of hot liquid distributors oriented to distribute hot liquid. The cooling tower top additionally has opposed parallel side walls unitarily connected to the bottom wall. In addition, the cooling tower top has opposed, parallel end walls connected to the bottom wall. The aforementioned side and end walls are unitarily connected to a top wall wherein the top wall has at least one opening formed therein for accommodating an air current generator. The top wall projects outwardly and downwardly from the opening.

[0015] There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0016] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0017] As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 is a perspective view of a cross-flow cooling tower in accordance with a first embodiment of the present invention.

[0019] FIG. 2 is a perspective view of a rotationally molded unitary frame assembly of the first embodiment of the present invention with tower covers unitarily attached to the opposing frame ends.

[0020] FIG. 3 is a top view of a top tower cover in accordance with the first embodiment of the present invention after the cover has been detached from an opposing end of the unitary frame assembly illustrated in FIG. 2.

[0021] FIG. 4 is a perspective view of the rotationally molded unitary frame assembly of the first embodiment of the present invention with the tower covers removed from the frame ends revealing the air intake ports of the frame assembly.

[0022] FIG. 5 is a perspective view of a cross-flow cooling tower in accordance with the first embodiment of the present invention with the rotationally molded unitary frame assembly shown in phantom.

[0023] FIG. 6 is a side cross-sectional view of a cross-flow cooling tower according to the first embodiment employing a rotationally molded, unitary frame assembly with top covers.

[0024] FIG. 7 is a perspective view of a second embodiment of a cross-flow cooling tower in accordance with the present invention.

[0025] FIG. 8 is a perspective view of a hot water distribution unit in accordance with the second embodiment of present invention.

[0026] FIG. 9 is a partial, cutaway view of the hot water distribution unit in accordance with the second embodiment of the present invention and showing a distribution pan or tray contained therein.

[0027] FIG. 10 is a perspective view of the underside of the hot water distribution unit of FIG. 9 in accordance with the second embodiment of the present invention.

[0028] FIG. 11 is a perspective view of an alternative two-piece hot water distribution unit in accordance with the second embodiment present invention.

[0029] FIG. 12 is a top view of a cold water collection basin in accordance with the second embodiment of present invention.

[0030] FIG. 13 is a perspective view a flow splitter employed in a preferred embodiment of the present invention.

[0031] FIG. 14 is a perspective view of a flow splitter employed in a preferred embodiment of the present invention.

[0032] FIG. 15 is a perspective view of two liquid collection basins that are molded together as one entity and then separated in accordance with an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED

EMBODIMENTS OF THE INVENTION

[0033] Referring now to the figures wherein like reference numerals indicate like elements, FIGS. 1-15 illustrate the presently preferred embodiments of a cross-flow cooling tower. While in the embodiment depicted the tower is a water cooling tower, it should be understood that the present invention is not limited in its application to water cooling towers, and can be used for other types of cooling towers.

[0034] Referring now to the first embodiment illustrated in FIGS. 1-6, a cross-flow cooling tower, generally designated 10, is illustrated for contacting generally horizontally flowing gas in a cooling relationship with generally vertically descending liquid. As seen in FIG. 4, the cooling tower includes a frame assembly 12 that is unitarily molded from polyethylene in a rotational mold, illustrated in FIG. 2, having a top 14, a bottom 16, two opposed side walls 18 and two opposed ends 20. More particularly, as seen in FIGS. 1-6, the tower is made up of a unitarily molded polyethylene frame assembly 12 reinforced by a mill galvanized steel skeleton 24, two upright fill assemblies 26, a hot water distributor 28 located above the fill assemblies 26, a vertical stack 30 extending upwardly from the hot water distributor 28, a cold water collection basin 32 below the fill assemblies 26, air intake ports 36, an exhaust port 39 and a cooling air current generator employing a fan unit 37. Skeleton 24 may be composed of other suitable materials such as stainless steel, hot dipped galvanized steel, epoxy coated steel, FRP (fiber reinforced plastic), etc. Fill assemblies 26 extend across the entire faces of air

intake ports 36. Only a few fill sheets are shown in assemblies 26 to add clarity to the structural features of tower 10.

[0035] After removal of the covers 34, the unitary frame assembly 12 includes two opposed side walls 18 that extend parallel to one another and are unitarily connected to a bottom generally planar wall and a top planar wall. The side walls 18 intersect the top generally planar wall to form the sides of the hot water distributor 28 above the fill assemblies 26 and intersect the bottom generally planar wall to form the side walls of the cold water collection basin 32 below the fill assemblies 26. As can be observed in FIG. 2, the opposed ends 20 of the frame assembly 12 intersect both the top and bottom generally planar walls of the cooling tower, forming the end barriers to the hot water distributor 28 and the cold water collection basin 32 respectively.

[0036] As illustrated in FIG. 2, initially, the unitarily polyethylene frame 12 is rotationally molded having solid opposing ends 20 wherein the cooling tower covers 34 are molded to be included within the opposing ends 20. Upon completion of the molding process, the solid opposing ends 20 and the tower covers 34 connected therein, are removed from the unitary frame 12 by a cutting means. The tower covers 34 are then prepared for installation and assembly above the hot water distributor 28. As a result of the removal of the tower covers 34, the opposing ends 20 of the cooling tower are designated air intake ports 36 when the tower is in operation. The aforementioned rotational molding of the unitary frame body 12 and following removal of the tower covers 34 offers a cost effective way for manufacturing and assembling a cross-flow water cooling tower by limiting the waste of manufacturing materials and by substantially reducing the amount of parts and assembly required.

[0037] In lieu of molding the tower covers 34 in opposed ends 20, louvers to prevent splash out of water may be molded into this face. Air inlet openings may be fabricated by removing the material around the intended louver structure. Molding the louvers in this face negates the requirement for attaching separate louvers or providing fill with integral louvers.

[0038] As illustrated in FIG. 4, the unitarily molded frame assembly 12 includes a hot water distributor 28 with a vertical stack 30 extending vertically therefrom and a cold water collection basin 32 disposed below the distributor. The frame 12 additionally includes two opposing side walls 18 that extend parallel to one another between the collection basin 32 and hot water distributor 28. The assembly also has two opposing intake ports 36.

[0039] The hot water distributor 28 contains a distribution pan or tray 38 positioned directly above the fill assemblies that permits water to gravitate through a plurality of apertures, perforations and/or nozzles 41 onto the top surfaces of the upper film sections of the fill assemblies 26. The water is supplied to the distribution pan or tray by way of supply pipe (not shown) and enters the assembly via the water inlet 40 shown in FIG. 1. Water is delivered to hot water distributor 28 and is distributed evenly to both sides with the aid of a generally inverted "V" shaped flow splitter 90 as illustrated in FIGS. 13 and 14. Flow control devices or valves are not required to balance the flow. Flow splitter 90 divides the flow and provides a barrier to prevent transitory or oscillatory flow variation from side to side.

[0040] The cold water collection basin 32 is disposed below the fill assemblies 26 in a position to receive liquid gravitating therefrom. The basin extends across the

entire width of the cooling tower 10 and may be coupled to a pumping structure (not shown) suitable for removing deposited liquid therein and for delivering the water to equipment requiring the same for cooling and/or returning the water to the supply source.

[0041] Referring now to FIG. 5, the polyethylene frame of the cooling tower 10 and components contained therein, are supported by conventional mill galvanized steel framework 24 as shown. The framework 24 offers support and strength to the tower frame while making the tower more durable, extending the cooling tower's operational life.

[0042] Polyethylene is a well-known plastic material used substantially for liquid containers such as milk jugs, and gallon gasoline containers. Polyethylene is a relatively inexpensive plastic and is dependable for containing liquids at low-pressure. However, polyethylene has relatively low material mechanical properties. The modulus of elasticity is only about 80,000 psi to 100,000 psi. By contrast the modulus of elasticity of steel is 29,000,000 psi which is about 300 times that of polyethylene. The implications for deflections are huge. For simple beams of the same geometry and loading, the one made of polyethylene will deflect 300 times the deflection of the steel beam. Therefore, to limit the deflections of polyethylene structures, the unsupported spans must be reduced very substantially and/or the cross-section increased very substantially compared to steel structures.

[0043] For example a simply supported beam subjected to a uniform load experiences a maximum deflection, Δ , according to following equation:

$$\Delta = 5 w L^4 / (384 EI) \dots\dots\dots(1)$$

in which

$w \equiv$ uniform load per unit length

$L \equiv$ length of simple span

$E \equiv$ modulus of elasticity

$I \equiv$ moment of inertia of the beam cross-section

To maintain the same deflection for a given span, L , and given uniform load, w , the product of EI for each beam must be constant:

$$E_p I_p = E_s I_s \dots\dots\dots(2)$$

in which subscripts p and s are polyethylene and steel respectively.

Solving for the required polyethylene moment of inertia gives the following equation:

$$I_p = I_s E_s / E_p \dots\dots\dots(3)$$

Taking the modulus of elasticity as 29,000,000 psi for steel and 100,000 psi for polyethylene, the required polyethylene beam moment of inertia is

$$\begin{aligned} I_p &= I_s (29,000,000 / 100,000) \\ &= 290 I_s \dots\dots\dots(4) \end{aligned}$$

For a simple rectangular beam cross-section the moment of inertia is computed as follows:

$$I = bh^3/12 \dots\dots\dots(5)$$

in which

$b =$ beam width

$h =$ beam height

Assuming a constant proportion of the width, b , to the height, h , the moment of inertia can be rewritten as:

$$I = \alpha h^4 / 12 \dots\dots\dots(6)$$

in which

$$\alpha \equiv b/h \quad \text{or} \quad b = \alpha h$$

Substituting equation 6 with respective subscripts for steel and polyethylene in equation 4 and solving for the height of the polyethylene beam cross-section gives the following equation:

$$\begin{aligned} h_p &= (290 h_s^4)^{0.25} \\ &= 4.13 h_s \dots\dots\dots(7) \end{aligned}$$

Therefore, the cross-section of the polyethylene beam must be over 4 times wider and over 4 times higher to carry the same load and maintain the same deflection for a given span.

The cross-sectional area, A, for the rectangular cross-section is

$$A = b h \dots\dots\dots(8)$$

Substituting the proportionality constant expression, $b = \alpha h$, from equation 6 gives the equation

$$A = \alpha h^2 \dots\dots\dots(9)$$

The cross-sectional area of the polyethylene beam, A_p , is

$$\begin{aligned} A_p &= \alpha h_p^2 \\ &= \alpha (4.13 h_s)^2 \\ &= 17.1 \alpha h_s^2 \\ &= 17.1 A_s \dots\dots\dots(10) \end{aligned}$$

Therefore, the cross-sectional area of the polyethylene beam is over 17 times that of the steel beam. The specific gravity of steel and polyethylene relative to water are about 7.85

and 0.94 respectively. Steel weighs about $7.85/0.94 = 8.4$ times as much as polyethylene for the same volume of material.

The volume of the beam, V , is

$$V = A L \dots\dots\dots(11)$$

The volume of the polyethylene beam may be expressed in terms of the volume of the steel beam as follows:

$$\begin{aligned} V_p &= A_p L \\ &= 17.1 A_s L \\ &= 17.1 V_s \dots\dots\dots(12) \end{aligned}$$

The weight of the beam is determined by multiplying the specific weight, γ , times the volume.

$$W_s = \gamma_s V_s \dots\dots\dots(13)$$

$$W_p = \gamma_p V_p \dots\dots\dots(14)$$

$$\begin{aligned} W_p &= (\gamma_p/\gamma_s) \gamma_s (17.1 V_s) \\ &= 17.1 (\gamma_p/\gamma_s) W_s \dots\dots\dots(15) \end{aligned}$$

The specific weight of steel, γ_s , is 490 lb/cf, and the specific weight of polyethylene is about 59 lb/cf. Therefore, the weight of the polyethylene beam compared to the weight of the steel beam may be expressed as follows:

$$\begin{aligned} W_p &= 17.1 (59/490) W_s \\ &= 2.06 W_s \dots\dots\dots(16) \end{aligned}$$

Therefore, the polyethylene beam is actually more than twice the weight of the steel beam.

Furthermore, rotationally molded polyethylene costs more per unit weight than does fabricated heavy mill galvanized (HMG) steel per unit weight. Thus, it is not economical to directly replace an HMG steel beam with a polyethylene beam as it would cost more than twice as much.

[0044] The yield strength of polyethylene ranges from about 1300 psi to 2800 psi. The yield strength of steel is about 36,000 psi, which is about 28 to 13 times the strength of polyethylene. However, polyethylene is a viscoelastic material which creeps (or moves) under sustained load. Long term sustained stress levels must be kept low to prevent this viscoelastic behavior from causing unacceptable deflections over time. Steel does not creep and is not subject to this limitation.

[0045] Taking the beam example above for constant deflections, the maximum bending stress, f_b , may be computed from the following equation:

$$f_b = M/S \dots\dots\dots(17)$$

in which

$$M \equiv \text{bending moment} = w L^2/8 \dots\dots\dots(18)$$

$$S \equiv \text{section modulus} = b h^2/6 = \alpha h^3/6 \dots\dots\dots(19)$$

The section modulus of the polyethylene beam may be expressed in terms of the section modulus of the steel beam as follows:

$$\begin{aligned} S_p &= \alpha h_p^3/6 \\ &= \alpha (4.13 h_s)^3/6 \\ &= 70.4 (\alpha h_s^3/6) \end{aligned}$$

$$= 70.4 S_s$$

Therefore, since the bending moment is assumed constant for the example, the maximum bending stress in the polyethylene beam may be expressed in terms of the maximum bending stress of the steel beam as follows:

$$\begin{aligned} f_{bp} &= M/S_p \\ &= M/(70.4 S_s) \\ &= f_s/70.4 \end{aligned}$$

Steel members are often sized for a maximum stress of about 0.6 of the yield strength which is 0.6 (36,000 psi) = 21,600 psi. The polyethylene maximum bending stress would be 21,600 psi/70.4 = 307 psi. This is about 0.1 to 0.2 times the yield strength of the polyethylene, which normally is sufficient to control creep.

[0046] The structural comparisons above show that polyethylene is not economical for structural applications. On the other hand steel is very well suited for structural applications and has been used in a wide variety of applications including unitary cooling towers. Polyethylene is corrosion resistant and formable by rotational molding into multiple functional shapes. The two materials compliment one another in a structural hybrid cooling tower design to produce a cost effective, durable product. A steel skeleton provides load paths to support the polyethylene components.

[0047] As illustrated in FIG. 6, the fill assemblies 26 of the tower employ up to a total of two film type fill packs or units which are aligned in a duplicate fashion in two opposed units so as to present a double-flow tower. Each of the units is made up of a plurality of upright, spaced apart film fill sheets of chevron or herringbone design. The film fill sheets are integrally constructed to include both louvers and eliminators, which

for example, may be the type illustrated in U.S. Pat. No. 4,548,766. Each of the units and thus the overall fill assemblies 26, present upright air inlet faces 42, opposed, upright air outlet faces 44, and a generally horizontal upper face 46 extending between the inlet face 42 and the outlet face 44. Therefore as a result of the individual fill assembly orientation, the gas inlet 42 and outlet 44 openings enable the flow of gas over substantially the entire vertical height of the fill assembly into the central plenum chamber 48 of the water cooling tower 10.

[0048] Alternatively, the air inlet 42 faces may be provided with stationary louvers 50 utilized to prevent water from splashing out of the tower. Again, these louvers may be rotationally molded in opposed ends 20 in lieu of basin covers 34. A drift eliminator wall 52 can be disposed across the air outlet faces 44 and in generally an upright position to prevent entrained droplets of water from entering the plenum chamber 48 as spray. The wall may be of any type for example, a honey-comb type eliminator or a series of spaced inclined baffles that permit the free flow of air there through but prevent significant quantities of liquid droplets from escaping the fill assemblies 26. An exemplary eliminator is disclosed in U.S. Patent 4,514,202. The fill assemblies 26, in conjunction with their respective eliminator walls, combine to form the tower's central plenum 48.

[0049] FIG. 6 illustrates that a vertical stack 30 is disposed above the hot water basin 28 and extends upwardly from the central plenum chamber 48 to define the exhaust port 39 of the cooling tower 10. The fan unit 37 is positioned within the stack 30 and is supported by horizontal support members 54 wherein the fan unit 37 employs a blade assembly coupled to a motor. Operation of the fan unit 37 causes currents of air

to be drawn through the fill assemblies 26 and forces the currents upwardly through the plenum chamber 48 into the vertical stack 30 for discharge through the exhaust port 39.

[0050] A variety of alternative components and designs can be used in the water cooling towers of the present invention. FIG. 7 illustrates a second embodiment of the present invention wherein a cooling tower 56 is displayed having a steel frame assembly composed of mill galvanized steel, and having a top, a bottom, two opposed side walls, two opposed ends. More particularly, the tower consists of two opposed mill galvanized cold-formed steel side walls 58 parallel to one another, two upright fill assemblies 60, a self contained hot water distribution unit 62 above the fill assemblies 60, a cold water collection basin 64 below the fill assemblies 60, air intake ports 63, an exhaust port 65 and a cooling air current generator employing a fan unit 66.

[0051] Referring now to FIGS. 7-11, and in accordance with the present invention, the hot water distribution unit 62 is rotationally molded from polyethylene in one operation to produce a single, self enclosed unit that includes a generally planar, distribution pan or tray 68 having apertures, perforations and/or nozzles 69, four walls 70 unitarily connected to tower covers 72, and an opening 74 for tower exhaust. The covers 72 project outwardly and downwardly from the opening 74. More particularly, the distribution unit 62 is a self contained unit having a water inlet 76, a first set of opposing side walls 70 parallel to one another and second set of opposing sides walls 70 parallel to one another. Both sets of walls 70 extend vertically from the pan or tray 68 and intersect the tower covers 72 to form a unitary enclosure, employed for the distribution of hot water having a fan shroud 78. Raised portions 73 are designed to manage water delivered to distribution unit 62. Most importantly raised portions 73 serve

to transform the inlet piping flow discharge disturbances into a more quiescent channel flow which is then released into distribution pans or trays 68. Another significant benefit of raised portions 73 is reduction in the amount of water inventory carried in distribution unit 62, which reduces the operating weight. The distribution unit 62 may be attached to the galvanized steel frame of the water cooling tower 56 by fastening means such as screw, welding, bolt, solder, and/or bracket.

[0052] In addition, as illustrated in FIG. 11, should the tower be sufficiently large such that a single piece distribution unit 62 would be impractical to rotationally mold, the distribution unit 62 may be rotationally molded as two or more individual pieces 67 that are subsequently joined together to form a distribution unit 62.

[0053] Referring now to FIG. 12, the cold water collection basin 64 is disposed below the fill assemblies 60 in a position to receive liquid gravitating therefrom. The cold water basin 64 is a rotationally molded, unitary piece having a generally planar bottom surfaces 80 and 81, a first set of opposed side walls 82 extending parallel to one another away from the bottom surfaces 80, 81 and a second set of opposed side walls 84 extending parallel to one another away from the bottom surfaces 80, 81. The basin 64 extends across the entire width of the cooling tower and may be coupled to a pumping structure suitable for removing deposited liquid therein and for delivering the water to equipment requiring the same for cooling and/or returning the water to the supply source. The cold water basin 64 may be attached to the galvanized steel frame of the water cooling tower by fastening means such as screw, welding, bolt, solder, and/or bracket.

[0054] In addition, should the tower be sufficiently large such that a single piece collection basin 64 would be impractical to rotationally mold, the cold water

collection basin 64 may rotationally molded as two or more pieces that are subsequently joined together to form a collection basin 64.

[0055] In accordance with an alternative embodiment of the present invention, the hot water distribution unit 62 and collection basin 64 illustrated in FIGS. 7-11 may be rotationally molded together as one entity and then separated as illustrated in FIG. 15. As illustrated in FIG. 15, two basins 92 and 94 respectively, are rotationally molded simultaneously in a single molding process. The basins 92 and 94 are then separated by a cutting element. The basins are then incorporated into a water cooling tower assembly as previously described, wherein basin 92 is employed as a hot water distribution element and basin 94 is employed as a cold water collection basin.

[0056] The aforementioned molding process is advantageous because it allows for the creation of an enclosed mold which reduces the amount of waste produced during the molding process. If the basins were to be molded separately, a temporary top would be required to be molded for each piece so that the basin mold could be closed. The molded, temporary top portion would then have to be cut away from the basin to open it up resulting in wasted material. This embodiment does not include basin covers, however the covers may be fabricated separately and added to the tower assembly.

[0057] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirits and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction

and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218